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CONTAMINATION OF VEGETATION AND SOIL BY LEAD AND OTHER
ELEMENTS IN THE VICINITY OF TORONTO REFINERS AND
SMELTERS LTD. 28 BATHURST ST., TORONTO - 1983, 1984,

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TORONTO REFINERS & SMELTERS LIMITED,

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C. E. DUNCAN, Acting Director
Air Resources Branch

**Contamination of Vegetation and Soil by Lead and other Elements
in the Vicinity of Toronto Refiners & Smelters Limited,
28 Bathurst Street, Toronto
- 1983, 1984, 1985**

**Air Resources Branch
Phytotoxicology Section**

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**Contamination of Vegetation and Soil by Lead and other Elements
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INTRODUCTION

The Phytotoxicology Section has conducted surveys of vegetation and/or soil contamination near Toronto Refiners & Smelters (TRS) annually since 1972. Results of tree foliage sampling conducted in 1982 and earlier years have revealed elevated levels of lead, arsenic, antimony and cadmium relative to the Gerrard Street Control Area in Toronto. However, average foliar levels of these contaminants near TRS in 1982 were considered to be the lowest measured since monitoring of tree foliage began in 1972.

METHODS

In September of 1983, 1984 and 1985, samples of Ailanthus foliage were collected from 11 or 12 stations in the vicinity of TRS (Figure 1), from the sides of trees facing the company. Control samples of Ailanthus foliage also were collected in September of each year from 10 stations in the Gerrard Street Control Area in downtown Toronto (Figure 2).

In addition to vegetation sampling, soil sampling at each station was conducted in 1983 and 1985. Surface soil scrapings (0-1 cm depth) were collected in 1983 in order to estimate the degree of foliar contamination due to soil re-entrainment. Soil samples of 0-5 cm depth were collected in 1985 in order to determine whether a build-up of soil contaminants had occurred since 1980, the year 0-5 cm soil sampling had last been conducted.

Distance and direction of sampling stations were calculated with reference to the main baghouse, which is indicated by a star in Figure 1.

Vegetation and soil samples were processed in the Phytotoxicology laboratory, and were analyzed for lead (Pb), arsenic (As), cadmium (Cd), and antimony (Sb), all of which are potential emissions from TRS, by the MOE Laboratory Services Branch. Additionally, samples collected in 1983 were analyzed for titanium (Ti), which was used as a tracer to estimate soil re-entrainment of lead.

In this report, results are compared with those of earlier years and with Phytotoxicology Section "upper limits of normal" guidelines which were developed

statistically (mean plus three standard deviations) from data for urban samples not considered to be influenced by emissions from industrial point sources.

RESULTS

Tree Foliage Results

Lead

Lead concentrations in unwashed Ailanthus foliage samples collected in September of 1983, 1984 and 1985 are shown in Table 1, and are compared with prior years' results. Whereas the 1982 levels were considered to be the lowest, on average, of any year since Phytotoxicology surveys were initiated, concentrations subsequently increased, with the 1985 levels being the highest (ave. 270 ug/g) of any year since at least 1977. The percentage of stations having foliar lead concentrations exceeding the "upper limit of normal" (60 ppm) in 1985 was 73%, vs a low of 45% in 1981-82 and a high of 90% in 1979.

These results indicate that lead emissions from TRS may have been greater in 1985 than during any previous year since 1979.

Effect of Rainfall

Washing of tree foliage samples collected near TRS in September of 1980, using a solution of 0.05% Alconox (soap) and EDTA (metal complexing agent), reduced foliar lead levels by an average of 57% when compared with unwashed samples. Amount and timing of rainfall also might reduce lead concentration results for samples analyzed "unwashed" in the lab, although the amount of such reduction might not be expected to be as large as that obtained by the relatively rigorous laboratory washing procedure. However, in order to ensure that inter-year comparisons of unwashed foliar lead results are valid, rainfall statistics should be examined. The figures in Table 2 show variation in rainfall, as measured at Pearson Airport, for the period 1977 to 1985. Total rainfall for the 2-week period and the 5-day period preceding the TRS sample collection dates are shown. The correlation coefficient between the 2-week rainfall and average foliar lead concentration was -0.04 (no relationship), while that between 5-day rainfall and foliar lead was -0.53. Although not significant at the 5% level, the latter correlation does indicate that rainfall prior to sample collection may reduce foliar lead concentrations, as expected. More importantly, it indicates that the variation in foliar lead levels near TRS from 1979 to 1985, particularly the relatively low levels in 1982, were at least partly the result of rainfall variation. However, the high foliar lead levels measured in 1985 near TRS cannot be ascribed solely to low amounts of rainfall, because both rainfall and foliar lead concentrations were lower in 1983 than in

1985. Also, rainfall levels were nearly as high in 1984 as in 1982, while average lead levels were more than twice as high in 1984 as in 1982. Therefore, it seems that a real increase in lead emissions from TRS has occurred since 1983.

Arsenic, Cadmium, Antimony

Arsenic, cadmium and antimony results for tree foliage collected near TRS in 1983, 1984 and 1985 are summarized in Table 3. Concentrations of all three elements considerably exceeded those in the Toronto control area, with the significance of the differences being antimony > arsenic > cadmium. However, cadmium concentrations were considered to be within normal levels for an urban area. Foliar levels of these elements did not increase dramatically in 1985 in the same manner as lead. The 1983 and 1985 average levels were approximately equal, and were higher than in 1984. These differences may reflect rainfall differences, with rainfall in the period preceding sample collection being greater in 1984 than in either 1983 or 1985 (Table 2).

Soil Results

Lead

Concentrations of lead in surface soil (0-5 cm depth) collected in 1985 in the vicinity of TRS are given in Table 4, and are compared with 1980 concentrations. (The 1983 results shown are for 0-1 cm depth and therefore direct comparisons cannot be made.) There is considerable variation inherent in soil sampling results, because metal levels in soils are seldom homogeneous even at a particular sampling station, especially in the vicinity of point sources. This variation, combined with possible site disturbances such as grading, resodding, etc., makes it risky to draw conclusions based on comparisons of single-site results for different years. However, it is possible to obtain a more valid indication of year-to-year changes in soil metal levels by comparing means for several stations. The data in Table 4 show that the average soil lead concentration for the 11 TRS sampling stations more than doubled from 5190 ug/g in 1980 to 11,745 ug/g in 1985. The largest increases, on a concentration basis, occurred at stations located along the east and south perimeter of the TRS property. In 1985, 91% of the sampling stations had above-normal (> 500 ug/g) soil lead levels, compared with 82% in 1980.

Arsenic, Cadmium, Antimony

Mean soil levels of other contaminants near TRS did not increase from 1980 to 1985 (Table 5). In fact, average soil levels of arsenic, cadmium and antimony decreased by 20%, 14% and 25%, respectively, during this period.

Estimating Re-entrainment Component of Foliar Lead Levels

As part of the 1983 sampling program, soil samples were collected from 0-1 cm depth in the vicinity of the regular Ailanthus sampling stations near TRS. Samples of soil and unwashed foliage were analyzed for titanium in addition to the regularly monitored contaminants. Titanium is ubiquitous in soils at fairly uniform concentrations and is not a component of emissions from secondary lead smelters. Also, it is not an essential element in plant nutrition and is not taken up by plants from soil. Therefore, the presence of titanium on unwashed tree foliage may be ascribed to soil re-entrainment. By comparing ratios of titanium and lead in both unwashed foliage and surface soil (0-1 cm depth), an estimate of lead in foliage due to soil re-entrainment may be obtained.

The results of this procedure are shown in Table 6. Re-entrained lead averaged 24% of total lead in foliage collected from 11 regular sampling stations near TRS in 1983. However, the relative significance of re-entrainment was greater at stations near the smelter than at more distant stations, probably due to very high soil lead levels in the immediate vicinity of TRS.

In 1980, re-entrainment had been estimated to be very significant along the highly contaminated south and east perimeter of the TRS property, contributing nearly all of the lead in Ailanthus foliage in this area. The 1980 estimates of the significance of re-entrainment at the more distant stations were more in line with the 1985 estimates, averaging 21% of the lead content of unwashed Ailanthus foliage. The 1980 estimates were regarded as being crude and subject to error because of a relatively small sample size and because 0-5 cm soil results and aluminum as a tracer (possible uptake by plants from soil) were utilized. However, some natural year to year differences in the significance of re-entrainment would be expected.

SUMMARY

Concentrations of lead, arsenic, cadmium and antimony in unwashed Ailanthus foliage collected in the vicinity of Toronto Refiners and Smelters in 1983, 1984 and 1985 were elevated with respect to the Gerrard Street Control Area in downtown Toronto.

Fluctuations in concentrations of lead and other contaminants in tree foliage near TRS, as observed from 1977 to 1985, particularly the relatively low levels which had been measured in 1982, were attributed at least partly to rainfall differences. However, an increase in foliar lead concentrations occurred from 1983 to 1985 which could not be explained by rainfall differences. Foliar arsenic, cadmium and antimony concentrations did not increase from 1983 to 1985.

Average concentrations of lead in surface soil near TRS increased greatly (126%) from 1980 to 1985. Arsenic, cadmium and antimony levels in soil decreased slightly during this period.

Soil re-entrainment was estimated in 1983 to have contributed an average of 24% of the lead content of unwashed Ailanthus foliage near TRS.

PH78/15

TABLE 1

Lead concentrations (ug/g, dry wt.) in unwashed *Ailanthus* foliage collected in September of 1977 and 1979 through 1985 in the vicinity of Toronto Refiners and Smelters.

Station	Distance (m) and Direction from Reference Point	Lead Concentration							
		1977	1979	1980	1981	1982	1983	1984	1985
8	150 NNE	<u>71</u>	<u>129</u>	49	54	33	<u>70</u>	56	<u>82</u>
10	330 NNE	34	<u>133</u>	28	17	16	25	22	48
52	550 NNE	-	-	-	-	-	-	(30)	(26)
1	125 NE	<u>272</u>	<u>217</u>	<u>125</u>	<u>310</u>	<u>81</u>	<u>727</u>	<u>240</u>	<u>410</u>
4	450 ENE	<u>65</u>	41	12	33	24	27	26	30
50	130 E	<u>310</u>	<u>162</u>	<u>92</u>	<u>126</u>	<u>81</u>	<u>95</u>	<u>190</u>	<u>1050</u>
51	170 E	-	-	<u>92</u>	<u>36</u>	<u>50</u>	<u>160</u>	<u>400</u>	<u>160</u>
43	60 ESE	<u>427</u>	<u>247</u>	<u>111</u>	<u>115</u>	44	<u>163</u>	<u>98</u>	<u>410</u>
36	40 SSW	-	<u>320</u>	<u>99</u>	<u>149</u>	<u>113</u>	<u>85</u>	<u>140</u>	<u>185</u>
30	145 WSW	<u>241</u>	<u>93</u>	58	43	<u>74</u>	<u>91</u>	<u>63</u>	<u>410</u>
29	50 NW	<u>191</u>	<u>113</u>	<u>88</u>	<u>413</u>	<u>131</u>	<u>273</u>	<u>250</u>	<u>140</u>
24	225 NW	43	<u>77</u>	32	17	16	23	29	40
TRS - Mean:		184	153	71	119	60	158	138	270
- Minimum:		34	41	12	17	16	23	22	30
- Maximum:		427	320	125	310	131	727	400	1050
Control Area - Mean (Ailanthus foliage):		40	54	21	18	14.9	19.7	15.5	19.8
% of stations exceeding current "upper normal" level* (underlined):		78	90	55	45	45	73	64	73

* Note - Phytotoxicology Section "upper limit of normal" lead concentration in unwashed urban tree foliage is 60 ug/g.

Table 2

Rainfall Statistics (Pearson Airport)

Year	Vegetation Collection Dates (TRS)	Rainfall in 2 week period prior to sample collection (mm)	Rainfall in 5 day period prior to sample collection (mm)	Average lead concen- tration (ug/g, dry wt.) in unwashed TRS tree foliage samples
1977	Sept. 29, 30	90.5	26.9	184
1979	Sept. 18	42.7	36.6	153
1980	Sept. 24	35.9	19.3	71
1981	Sept. 23	20.4	15.8	119
1982	Sept. 28	66.8	35.2	60
1983	Sept. 14, 15	1.2	0	158
1984	Sept. 12	52.9	27.1	138
1985	Sept. 18	36	0	270

Table 3

Summary of arsenic, cadmium and antimony levels (ug/g, dry weight) in unwashed tree foliage near Toronto Refiners & Smelters - 1983, 1984, 1985

Statistical Parameter	Arsenic	Cadmium	Antimony
1983 - mean	4.6	0.62	7.1
- minimum	0.36	0.1	0.29
- maximum	33.7	2.4	48.2
- % of stations with "above-normal" concentrations	45	0	73
- control area mean	0.11	< 0.1	0.09
1984 - mean	0.94	0.24	2.7
- minimum	0.22	< 0.1	< 0.03
- maximum	2.1	0.5	6.7
- % of stations with "above-normal" concentrations	9	0	73
- control area mean	0.14	< 0.1	0.06
1985 - mean	3.4	0.78	7.0
- minimum	0.47	0.1	0.36
- maximum	6.6	2.3	19.4
- % of stations with "above-normal" concentrations	45	0	91
- control area mean	0.14	< 0.1	0.12
Phytotoxicology Section "upper limits of normal" concentrations in unwashed urban tree foliage	2	3*	0.5

* under review

Table 4

Lead concentrations (ug/g, dry weight) in surface soil
collected in the vicinity of Toronto Refiners and Smelters - 1980, 1983, 1985

Station No.	Distance (m) and Direction from Reference Point	Lead Concentration			% Change 1980-1985
		1980 (0-5 cm)	1983 (0-1 cm)	1985 (0-5 cm)	
8*	150 NNE	<u>1050</u>	2400	<u>570</u>	-46
10	330 NNE	365	650	<u>1750</u>	379
52	550 NNE	-	-	(710)	-
1	125 NE	<u>12000</u>	4000	<u>51000</u>	325
4	450 ENE	<u>1000</u>	850	<u>1200</u>	20
50	130 E	<u>12000</u>	5530	<u>26500</u>	121
51	170 E	<u>4400</u>	1270	<u>9850</u>	124
43	60 ESE	<u>4300</u>	56000	<u>17500</u>	307
36	40 SSW	<u>17000</u>	5400	<u>1450</u>	-91
30	145 WSW	<u>3100</u>	2400	<u>14500</u>	368
29	50 NW	<u>1550</u>	8670	<u>4500</u>	190
24*	225 NW	325	470	380	17
Mean soil lead concentration:		5190	7967	11745	126
Control area mean concentration:		353	750	316	-10.5
% of stations exceeding current "upper normal" level (underlined):		82	-	91	

Note - Phytotoxicology Section "upper limit of normal" lead concentration in urban
soil (0-5 cm depth) is 500 ug/g.

* Sampling station located on residential or public property (residential
boulevards, parkland)

Table 5

Summary of arsenic, cadmium and antimony levels (ug/g, dry weight)
in surface soil near Toronto Refiners & Smelters - 1980, 1983, 1985

Statistical Parameter	Arsenic	Cadmium	Antimony
1980 (0-5 cm depth)			
- mean	198	24.7	220
- minimum	7.4	0.5	4.5
- maximum	781	118	906
- % of stations with "above-normal" concentrations	82	64	82
- control area mean	7.2	1.0	3.9
1983 (0-1 cm depth)			
- mean	368	56.6	181
- minimum	5.2	1.3	7.1
- maximum	3575	543	1212
- control area mean	4.0	1.1	1.6 (35.5)
1985 (0-5 cm depth)			
- mean	158	21.2	166
- minimum	6.7	1.0	3.1
- maximum	480	80	956
- % of stations with "above-normal" concentrations	73	82	82
- control area mean	5.9	0.86	2.9
Phytotoxicology Section "upper limits of normal" concentrations in urban surface soil (0-5 cm depth)	20	4	8

Table 6

Estimated contribution from soil re-entrainment to lead content of *Alnus* foliage in the vicinity of Toronto Refiners & Smelters (TRS), Toronto - September, 1983.

Sample Group	Statistics	Tree Foliage (unwashed)			Surface Soil (0-1 cm)			Estimated ppm Pb in Foliage due to Re-entrainment (soil property)	Re-entrained Pb as % of Total Pb	Enrichment Factor (E.F.)**
		Pb (ppm)	Tl (ppm)	Pb/Tl	Pb (ppm)	Tl (ppm)	Pb/Tl			
"High Pb" TRS stations (>90 ppm Pb, mean distance 113 m from TRS) (n=8)	Mean	251	11.1	28.9	12980	2410	8.9	48.7	31.3	17.3
	+ S.D. *	+ 243	+ 8.0	+ 26.4	+ 21230	+ 480	+ 12.4	+ 61.2	+ 40.7	+ 22.7
	Minimum	91	5.2	3.5	1270	1730	0.88	3.4	2.1	1.0
	Maximum	730	27	79	50000	2840	32	168	104	47
"Low Pb" TRS stations (<90 ppm Pb, mean distance 240 m from TRS) (n=5)	Mean	46	12.8	3.7	1950	2920	0.68	8.3	15.8	7.6
	+ S.D.	+ 29	+ 2.1	+ 2.4	+ 2070	+ 520	+ 0.68	+ 8.2	+ 7.3	+ 3.5
	Minimum	23	10.2	1.6	470	2090	0.14	1.8	7.8	3.9
	Maximum	85	18	7.1	5400	3460	1.8	22	26	12.9
All TRS stations (mean distance 170 m from TRS) (n=11)	Mean	158	11.9	17.5	7970	2840	4.1	30	24	13
	+ S.D.	+ 204	+ 5.9	+ 22.9	+ 16130	+ 550	+ 9.3	+ 48	+ 30	+ 17
	Minimum	23	5.2	1.6	470	1730	0.14	1.8	2.1	1.0
	Maximum	730	18	79	50000	3460	32	168	104	47
Gerrard Street Control Area, Toronto (n=10)	Mean	20	11	2.0	750	3250	0.23	2.1	13	15
	+ S.D.	+ 8.6	+ 4.1	+ 1.1	+ 870	+ 390	+ 0.25	+ 1.6	+ 10	+ 17
	Minimum	8	7.0	0.72	230	2280	0.088	0.59	1.6	2.7
	Maximum	38	18	4.0	3130	3620	0.90	6.4	38	61

S.D. = Standard Deviation

$$**E.F. = (Pb_{(F)}/Tl_{(F)}) \div (Pb_{(SY)}/Tl_{(SY)})$$

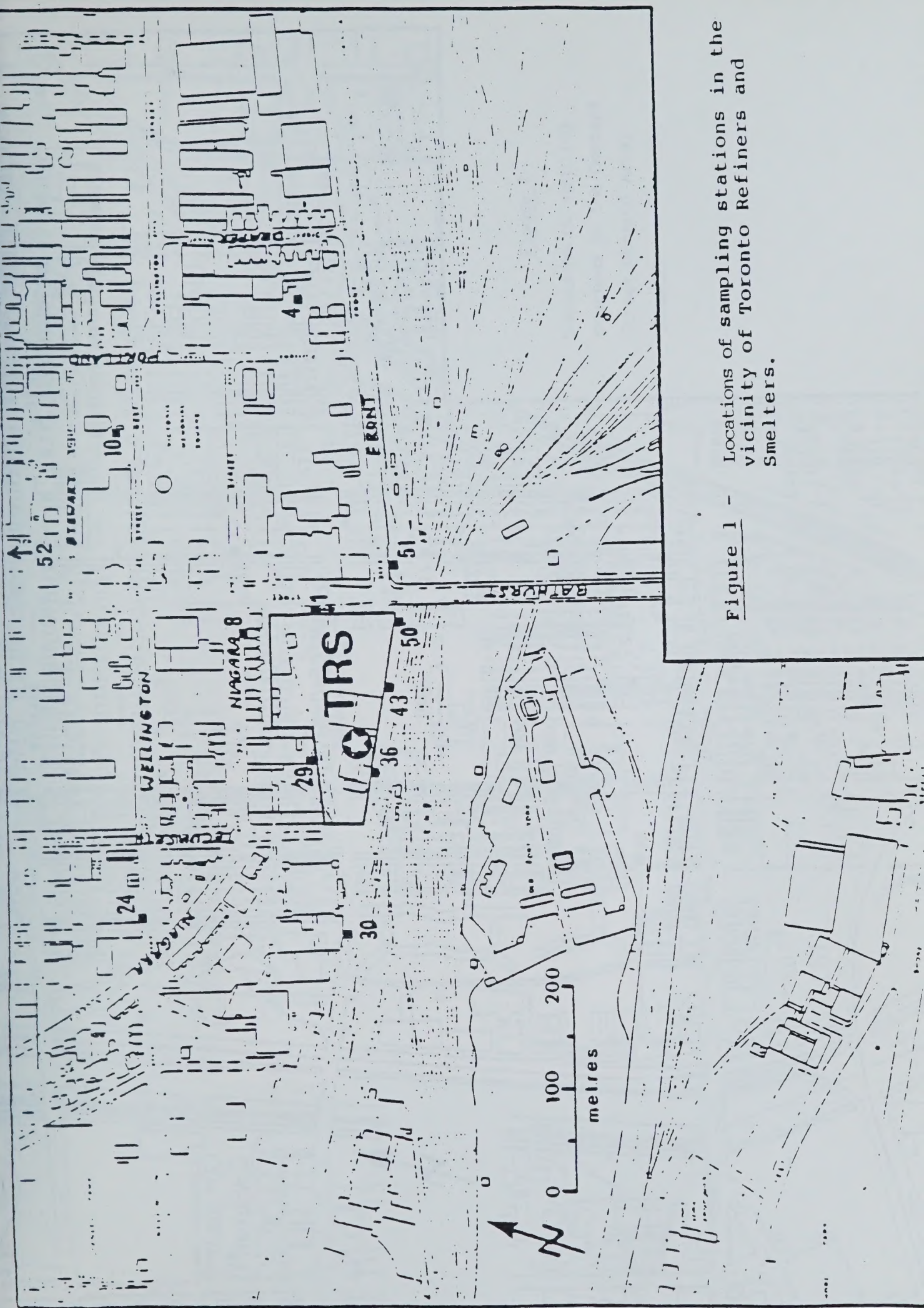


Figure 1 - Locations of sampling stations in the vicinity of Toronto Refiners and Smelters.



Figure 2

Locations of sampling
stations in the Gerrard
Street Control Area,
Toronto.

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